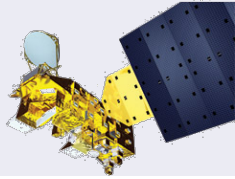

Is the Globe Darkening?
Cimate Models and Observations.

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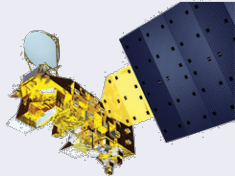
Jet Propulsion Laboratory
California Institute of Technology

April 3, 2019

Outline



Energy Balance

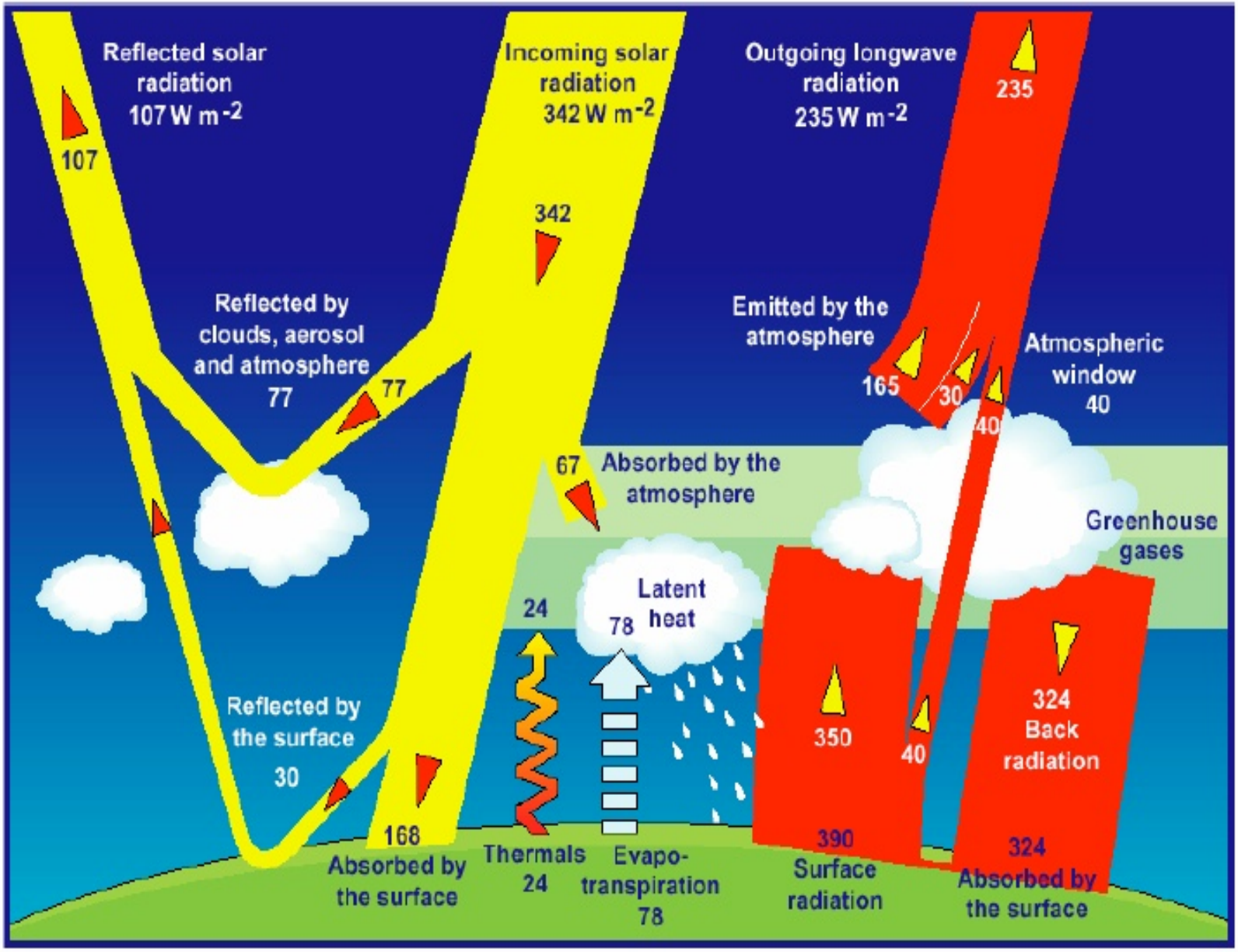
Climate Model Intercomparison Project

CERES Observations

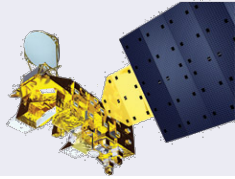
AIRS Observations

Darkening?

The global climate is based on the balance between The incident solar radiation and RSR and OLR



Climate models



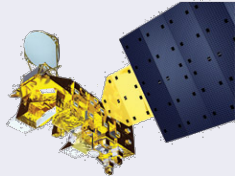
The incident radiation from the Sun is constant.

Climate is the result of the balance between the Outgoing Longwave Radiation (OLR) and the Reflected Shortwave Radiation (RSR).

If RSR is constant, but the OLR decreases we have the classical greenhouse effect and the surface warms.

If the RSR decreases, but the OLR stays constant we have the darkening of the globe and the surface warms.

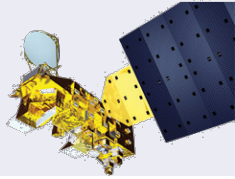
If the energy balance is disturbed, the global climate will find a new colder or warmer equilibrium



The injection of co2 into the atmosphere disturbs the energy balance

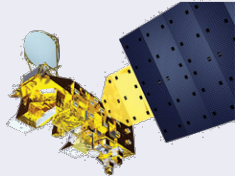
Susskind (AIRS data) and Loeb (CERES data) have shown that since 2002 OLR decreased at the rate of 0.5 W/m2/decade.

Climate models



Climate models can be used to predict what happens when the atmospheric co2 increases at the rate of 1%/year since 1885.

Climate models



Climate models have been used to predict what happens when the atmospheric co2 increases at the rate of 1%/year since 1885.

Climate model react in a counter-intuitive way

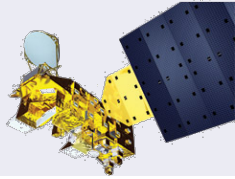
Trenberth KE, Fasullo JT, Kiehl J. Earth's global energy budget. Bull Am Meteorol Soc. (2009), 90(3):311–324.

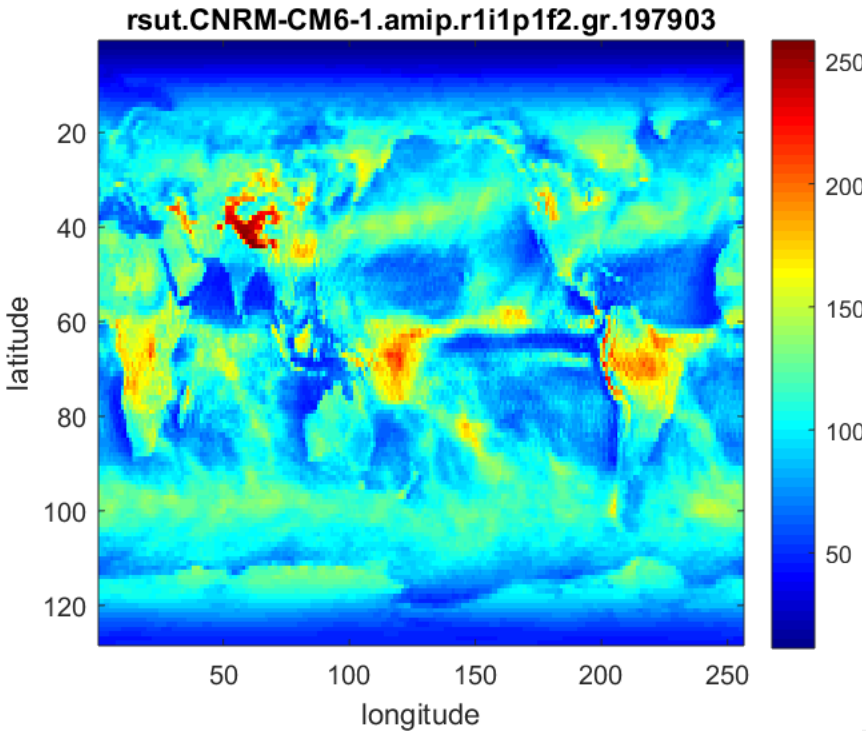
reported that in the 1%/year co2 increase scenario the CMIP3 models show little change in the OLR, and most of the warming is due to a decreased RSR, the Earth is getting darker.

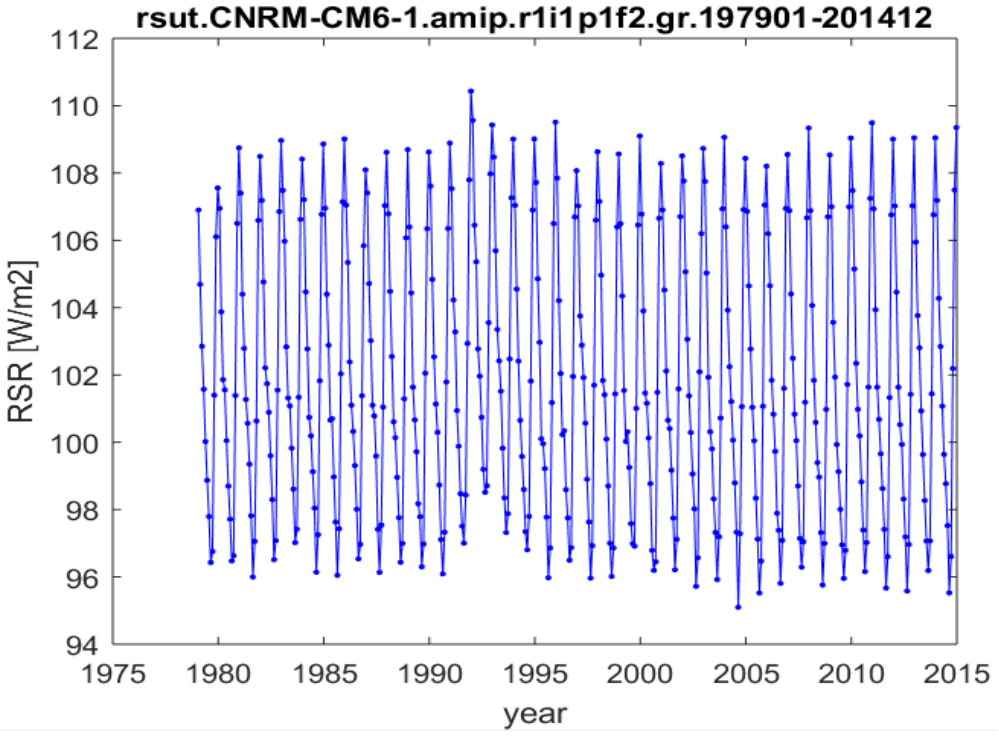
Donahoe, A., K.C. Armour, A.G. Pendergrass and D.S. Battisti (2014) Shortwave and longwave radiative contributions to global warming under increasing CO2. Proc.Natl.Acad.Sci USA 2014 Nov 25,111(47): 16700-16705 doi) 10.1073/pnas.1412190111.

(Figure 4D) found that the RSR decreases steadily at the rate of about -0.2W/m2/decade. The globe is getting darker.

This result is confirmed by the early results From CMIP6

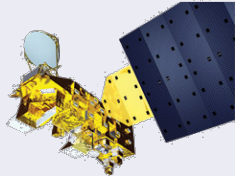






In the 4 CMIP6 results currently available
the trend in the RSR is -0.14 %/decade with 0.6%/decade uncertainty.

RSR measurements are the task of CERES



Loeb, N. G. and David R. Doelling "Clouds and the Earth's Radiant Energy System (CERES) Energy Balanced and Filled (EBAF) Top-of-Atmosphere (TOA) Edition-4.0 Data Product J. Climate (2018) Vol. 31, No. 2

Loeb et al. (2018, Table 7) claims a trend of

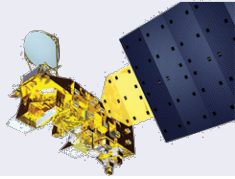
-0.20±0.23 W/m2/decade for CERES Ed2.8
-0.39±0.23 W/m2/decade for the CERES Ed4.0 EABF

This result is consistent with darkening of the globe.

The error bars are large

The CMIP5 and CMIP6 trends agree with CERES

RSR measurements are the task of CERES



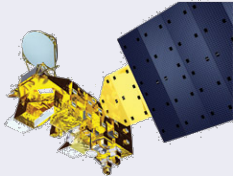
The reason for the large error bars in CERES Ed2.8 is the availability of a stable calibration reference.

CERES uses a solar diffuser made of Spectralon.

MODIS Aqua and Terra also use a solar diffuser made of Spectralon. Degradation of the MODIS solar diffuser have been reported (Chen et al, 2017). The effort at correcting this has big error bars.

H. Chen, X. Xiong, A. Angala, Z. Wang, and A. Wu "MODIS Solar Diffuser On-orbit Degradation Characterization Using Improved SDSM Screen Modeling" SPIE.2017

The trend in the RSR can be measured using AIRS data



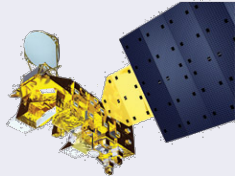
Aumann et al. (2012) showed that vis2 signal measured in RU times and effective bandwidth is a very good approximation to the Reflected Shortwave Radiation (RSR) measured by CERES Aqua.

Aumann, H. H., A. Ruzmaikin, and A. Behrangi, (2012) On the surface temperature sensitivity of the reflected Shortwave, Outgoing Longwave and Net Incident Radiation, J.Clim. 25, 6585-6593 DOI: 10.1175/JCLI-D-11-00607.1

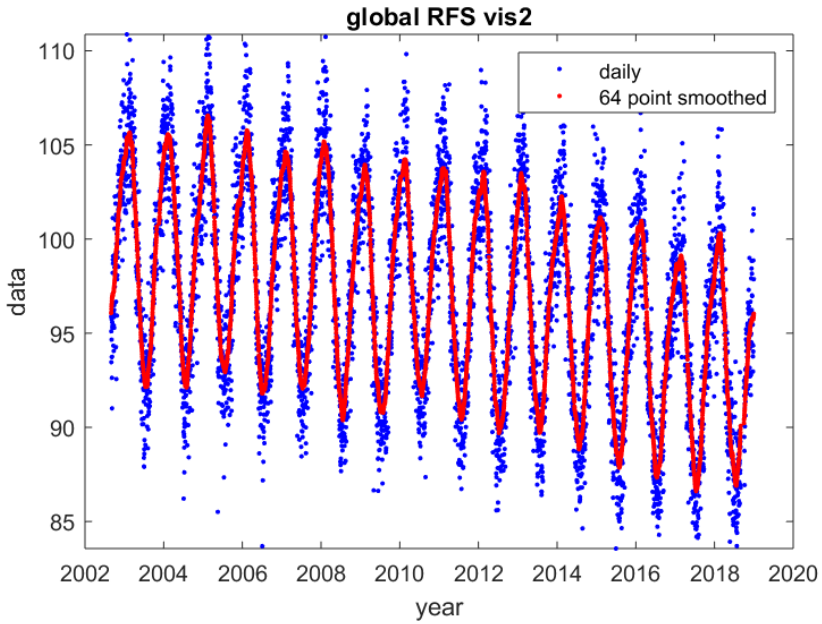
National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

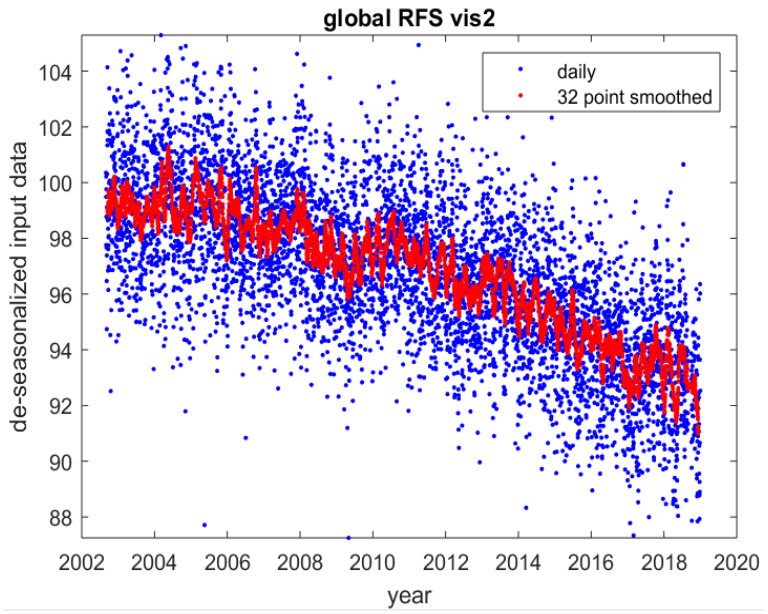
Atmospheric Infrared Sounder

The RSR measurements with AIRS have a trend due to the increased contamination of the scan mirror



The RSR measurements are based on the daily global mean of 21000 Random Full-swath Spectra (RFS)

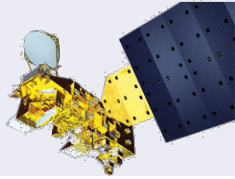




The RSR varies seasonally in response to the eccentricity of the Earth orbit

The seasonal variation can be removed, but the trend of 0.45%/year remains

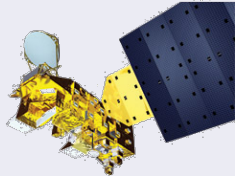
AIRS uses Deep Convective Clouds as perfect diffuser of solar radiation.



Doelling, D. R., Luis Lguyen, P. and P. Minnis, "On the use of deep convective clouds to calibrate AVHRR data", Earth Observing System IX Conference, International Symposium on Optical Science and Technology SPIE 49th Annual Meeting, Denver, Colorado, 2-6 August 2004.

Aumann, H. H., T. Pagano and M. Hofstadter (2007) „ Observations of Deep Convective Clouds as stable reflected light standard for climate research: AIRS evaluation " SPIE Optics-Photonics Meeting 26-30 August 2007, San Diego, California.

AIRS uses Deep Convective Clouds to correct for the change in the scan mirror reflectivity



With a solar diffuser the optical path used for the scene observations and the diffused Sun are different. The path includes an attenuator, which may contribute to a signal degradation.

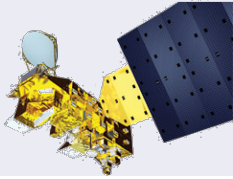
For AIRS the optical path used for the scene observations and the DCC are identical.

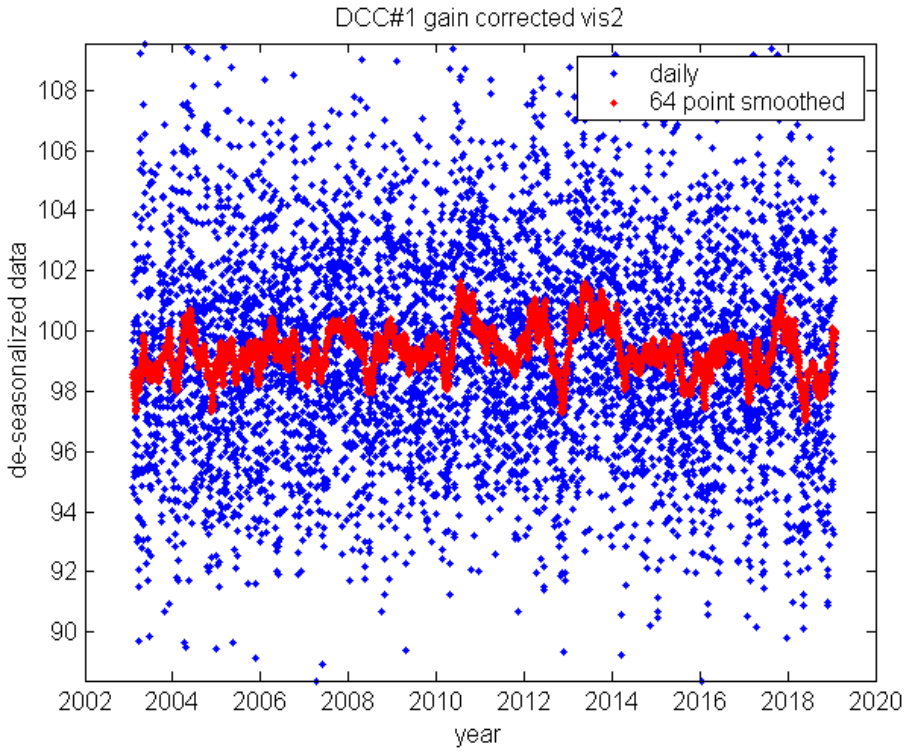
To use the DCC for as solar diffusers one had to

1) Detect the DCC. AIRS uses the 1231 cm-1 window channel to detect about 2000 DCC colder than 200K each day.
2) Have a signal chain which can handle the large DCC signal.

The signal from the random scene is typicaly 100 RU,
The signal from the DCC is typically 400 RU

The trend in the RSR is zero with high confidence

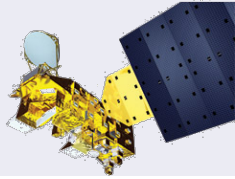




The trend in the RSR is -0.005 %/decade with 0.1%/decade uncertainty

The 2 sigma confidence range of the RSR trend is -0.25 to +0.15 W/m2/decade

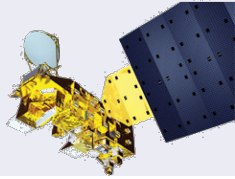
Observations and model result overlap using 2 sigma confidence ranges of the RSR trend



AIRS	-0.25	to +0.15	W/m2/decade
CMIP6	-0.26	to +0.07	W/m2/decade
CERES EBAF	-0.62	to -0.16	W/m2/decade

CMIP6 agrees better with AIRS than CERES.

Summary



The RSR trends from AIRS, CMIP6 and CERES overlap for the 2 sigma range.

The globe is not darkening according to AIRS

The globe is darkening according to CERES

4 CMIP6 models are leaning a little toward darkening, but we have results from only 4 of 15 models